RESEARCH DEPARTMENT

THE U.H.F. TELEVISION SURVEY OF 1957/8: OBJECTIVE MEASUREMENTS COMPARED WITH SOME SUBJECTIVE ASSESSMENTS

Report No. T-072

(1960/8)

G.F. Newell, A.M.I.E.E.
E.W. Taylor, M.A.

ABHowe

(A.B. Howe)

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SUMMARY

This report describes objective measurements of signal-to-noise ratios and of waveform distortion using a 'pulse-and-bar' test waveform. The results of these measurements are compared with subjective assessments. The agreement is fairly good in view of the fact that the objective measurements did not include noise or waveform distortion occurring at the picture source, although the subjective assessments would have been influenced by any such noise or distortion.

The results show that if the peak-to-peak noise is less than 8% of the double-amplitude-peak video signal, as measured with a waveform monitor, the most probable subjective assessment of overall picture quality would be "good". If the noise-to-signal ratio is between 8% and 20%, an assessment of "fairly good" is indicated.

As regards waveform distortion, the results show that a distortion rating of 3% would indicate a 90% probability of a subjective assessment of overall quality in the grade 1 or 2, "excellent or good". A rating of 7·5% indicates a 50% probability of such an assessment.

1. INTRODUCTION

The subjective assessments made during the comparison tests carried out under the auspices of the T.A.C./T.S.C. and B.B.C. Working Party in 1957/8 have been fully described elsewhere.[1] These tests extended over several months and necessitated large numbers of measurements being made in a wide range of reception conditions. Specially equipped mobile laboratories travelled along radial routes from Crystal Palace making assessments of reception conditions at sites along the routes. It was decided to take advantage of the opportunity, thus provided, to make some objective measurements at each site for comparison with the subjective assessments. The measurements were not completely objective because they required visual assessment of trace displacements on a cathode-ray tube screen. However, as this assessment was aided by the use of superimposed graticules and masks, it was felt that such measurements would be considerably more independent of the observer than was the case with purely subjective assessments of picture quality judged by visual inspection of a picture monitor. Besides measurements of the ratio of signal-to-noise or -interference, it was decided to make measurements of waveform distortion using the pulse-and-bar test waveform.[2] Although these pulse-and-bar tests have proved extremely useful in measuring the performance of television links, they were originally intended for use with noise-free, linear networks, but it was hoped that the usefulness of the method for assessing the service area of a vestigial-sideband television broadcasting station might be assessed. The main purpose of the programme was to make the subjective assessments and the limited amount of time available for the objective measurements made it impossible to make more than a few simple measurements at each site.

This report describes the measurements made by the B.B.C. mobile laboratory and the degree of agreement between the objective measurements and the subjective assessments.

2. THE OBJECTIVE MEASUREMENTS

The mobile laboratory[3] was equipped with apparatus for the simultaneous reception of a television signal having a carrier frequency of 45 Mc/s (Channel 1) and one having a carrier frequency of 654·25 Mc/s (Band V). The video waveforms obtained from these signals were supplied to a picture monitor for subjective assessment and to a precision waveform monitor for objective measurements. One of these measurements consisted of visual estimation of the peak-to-peak deflexion of the cathode-ray tube trace due to the video waveform and that due to the random noise, or interference. By using one line of each picture (during the field blanking period) for the noise measurement, the error introduced by mains hum was reduced. This also ensured that the noise was not due to the picture source but was a function of the site and field strength.

The same monitor was used for measuring the waveform distortion. For this purpose a special 'pulse-and-bar' test waveform[2] was transmitted. The test waveform was inserted in the field blanking period (line number 11) thus causing no interference with the picture, and was viewed on the monitor through an edge-illuminated perspex mask engraved with limit patterns which enabled the various symptoms of waveform distortion to be evaluated. The pulse was approximately "sine squared" in shape with a half-amplitude duration of 0·33 μs, the bar waveform had a duration of approximately 40 μs, and both it and the pulse had amplitudes which were 70% of the excursion from blanking level to peak white. These measurements, which were carried out only during the Series A (405-line) tests, corresponded to a simplified version of the "routine test method" described by Lewis.[2] The 0·33 μs pulse and the 40 μs bar were Lewis's "2T pulse" and "bar".

Lewis's method entailed measurements of the following characteristics:

(a) The response to a 50 c/s square-wave test signal.
(b) The uniformity of the 40 μs bar waveform.
(c) The relative amplitudes of the 2T-pulse and bar waveforms.
(d) The width at half amplitude of the 2T-pulse.
(e) The response to the 2T-pulse, weighted according to the time difference relative to the centre of the pulse, but ignoring the central region between the half-amplitude points. This measurement included the "skirts" of the pulse, any oscillations before or after it, and any echoes.
(f) Various features of the response to a 0·17 μs T-pulse.

Of these characteristics, only (b), (c) and (e) were measured. By means of the masks, numerical values could be assigned to them and the biggest of the four ratings (referred to later as "maximum rating %") was taken for comparison with the subjective assessment of picture quality. This procedure did not take full advantage of the test waveform for diagnosis or measurement of distortion, but was adopted in view of the limited time available for the measurements and the subsequent computation. Nevertheless, if the measurements could be shown to correlate well with the subjective assessments, a simple and useful procedure would be confirmed for future use.

3. THE SUBJECTIVE ASSESSMENTS

These assessments were made separately by two observers seated 4 ft (1·2 m) from a 21 in. (53 cm) picture monitor. The lighting in the mobile laboratory was subdued but sufficient for the observers to read and fill in their test report forms. The observers made assessments of seventeen parameters of the picture. We are here concerned only with two of these parameters; they are:

I. Noise (random) which was assessed using the scale:

1 Imperceptible
2 Just perceptible
3 Definitely perceptible but not disturbing
4 Somewhat objectionable
5 Definitely objectionable
6 Unusable

II. Overall assessment of picture using the scale:

1 Excellent
2 Good
3 Fairly good
4 Rather poor
5 Poor
6 Very poor

4. RESULTS

4.1. General

It was found that the method of objective measurement used was very unsuitable for measuring ignition interference because only one line in each picture was inspected. This, and the fact that the objective and subjective measurements were not made at exactly the same instant, resulted in a poor correlation between the sets of measurements for ignition and similar erratic interference.

When continuous wave interference was encountered it was usually accompanied by a high level of random noise. Small amounts of c.w. interference are often difficult to observe in the presence of a high level of random noise, and it was found that often the objective measurement recorded c.w. interference when the subjective assessment did not include reference to this defect, and vice versa. All sites at which either measurement or assessment included c.w. interference have been omitted from this analysis. Similarly, if ignition interference was predominant in either test, the site has been omitted from this analysis.

4.2. Noise

The statistical frequency distribution of subjective assessment of noise for various objective noise-to-signal ratios is tabulated in Table 1 for Series A, Channel 1, and in Table 2 for Series A, Band V. The same information for Series B results is shown in Tables 3 and 4. These tables show the mean subjective noise grade, and the standard deviation from that mean, for each noise-to-signal ratio.

TABLE 1

CHANNEL 1, SERIES A

Distribution of noise measurements against noise assessments

Peak-to-peak noise / d.a.p. video signal %	No. of Samples	Per cent samples in subjective noise assessment grade heading column						Mean subjective grade	Standard deviation from mean
		1	2	3	4	5	6		
2·5	4	50	25	25				1·75	0·85
4·0	20	30	55	15				1·85	0·65
5·0	31	23	71	6				1·85	0·5
6·0	28	7	57	32	4			2·3	0·65
7·5	22	27	46	27				2·0	0·75
10·0	33		52	45	3			2·5	0·55
12·5	12		50	50				2·5	0·5
20·0	12			42	50	8		3·9	0·65

TABLE 2

BAND V, SERIES A

Distribution of noise measurements against noise assessments

Peak-to-peak noise / d.a.p. video signal %	No. of samples	Per cent samples in subjective noise assessment grade heading column						Mean subjective grade	Standard deviation from mean
		1	2	3	4	5	6		
2·5	34	15	70	15				2·0	0·55
3·5	42	12	78	10				2·0	0·45
4·0	110	15	67	18				2·0	0·45
5·0	119	9	56	35				2·3	0·6
6·0	46	9	54	35	2			2·3	0·6
7·5	51	6	20	57	17			2·6	0·8
10·0	63		19	60	18	3		3·0	0·7
15·0	56		5	55	36	4		3·4	0·65
20·0	21			29	66	5		3·6	0·5
25·0	10			20	60	20		4·0	0·65
30·0	20				45	55		4·5	0·5
40·0	36				45	47	8	4·6	0·65
50·0	20			10	25	55	10	4·65	0·8
60·0	14				7	72	21	5·1	0·5
75·0	10					60	40	5·4	0·5
100·0 +	28					21	79	5·8	0·4

TABLE 3

CHANNEL 1, SERIES B

Distribution of noise measurements against noise assessments

Peak-to-peak noise / d.a.p. video signal %	No. of samples	Per cent samples in subjective noise assessment grade heading column						Mean subjective grade	Standard deviation from mean
		1	2	3	4	5	6		
2·0	4	75	25					1·25	0·45
4·0	18	67	33					1·3	0·45
5·0	22	68	32					1·3	0·45
6·0	12	17	83					1·8	0·4
7·5	10		90	10				2·1	0·3
10·0	16	6	82	12				2·1	0·45
15·0	8			75	25			3·3	0·45
25·0	8			50	38	12		3·6	0·7
40·0	6			50	50			3·5	0·7
50·0	8				25	75		4·8	0·45
75·0	4					75	25	5·25	0·45
100·0 +	5				20	40	40	5·2	0·75

TABLE 4

BAND V, SERIES B

Distribution of noise measurements against noise assessments

Peak-to-peak noise / d.a.p. video signal %	No. of samples	Per cent samples in subjective noise assessment grade heading column						Mean subjective grade	Standard deviation from mean
		1	2	3	4	5	6		
1·0	8	88	12					1·1	0·35
1·5	8	100						1·0	0·0
2·0	20	80	20					1·2	0·4
2·5	8	88	12					1·1	0·35
3·0	18	94	6					1·05	0·25
4·0	32	72	28					1·3	0·45
5·0	56	61	37	2				1·4	0·55
6·0	44	36	64					1·6	0·5
7·5	32	34	63	3				1·7	0·5
9·0	15	20	73	7				1·95	0·45
10·0	42	5	64	31				2·3	0·55
12·5	24	4	50	46				2·4	0·6
15·0	44		39	50	11			2·7	0·6
17·5	24		17	79	4			2·85	0·45
20·0	20		5	80	15			3·1	0·45
22·5	23		9	43	48			3·4	0·65
25·0	26			34	58	8		3·75	0·6
30·0	12			33	25	42		4·1	0·85
35·0	12			33	50	17		3·8	0·65
40·0	18			28	44	28		4·05	0·75
50·0	29				38	62		4·65	0·5
60·0	26				11	62	27	5·15	0·6
75·0	22				9	64	27	5·2	0·55
100·0 +	56				2	21	77	5·75	0·5

The standard deviation is less than one grade in all cases and is frequently below a half-grade. The mean values from the tables are plotted in Fig. 1. The curves for Series A have higher subjective grades than those for Series B for any given noise-to-signal ratio. The Series A tests were carried out in the winter of 1957/8 and the Series B tests in the following spring and summer and it is possible that some change in subjective criterion may have occurred over this time. It is thought, however, that one important cause of the discrepancy was due to the fact that, for Series A, the test pictures consisted of normal programmes, whilst in Series B only films and slides were used. The objective measurement ignored any noise originating in the programme source and transmitted with the picture, but the subjective assessment of noise would, of course, include this. The Series A curves have an asymptote of about 1·8 on the subjective-grade scale. The Series B curves show this grade to be equivalent to noise with a peak-to-peak amplitude equal to 8% of the d.a.p. video signal, and this is a very reasonable average for normal programmes, including winter outdoor broadcasts, etc. From this it appears that the average noise grading of pictures transmitted in the winter of 1957/8 was about 2 or "just perceptible". Similarly it would appear that the average noise grading of the pictures transmitted in the Series B tests, films and slides, was about 1·2 or almost "imperceptible". In spite of these differences between the Series A and Series B results, the agreement is fairly good and the method of measuring noise-to-signal ratio with a waveform monitor gives close agreement with subjective noise assessments. It is interesting to see that the Series B curves for Channel 1 and Band V agree so closely, in view of the fact that the former used 405-line standards while the latter used the 625-line standards adopted by Western European countries. This result appears to conflict with the results of video comparisons carried out by Weaver.[4]

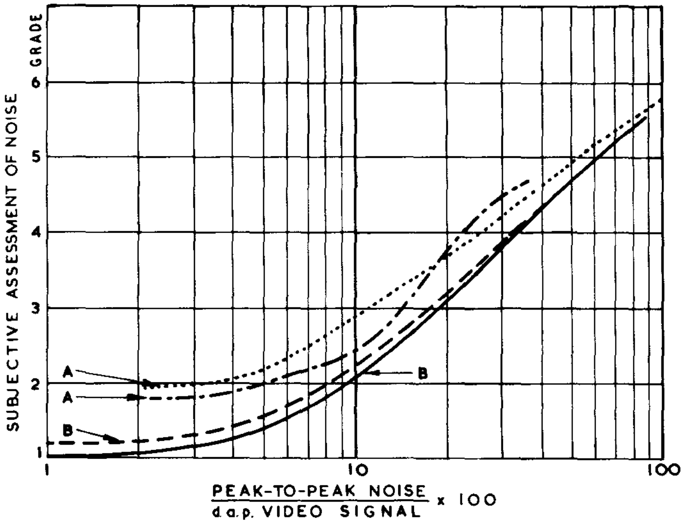

Fig. 1 - Mean subjective noise assessment plotted against noise level

—·— Series A Channel 1
········ Series A Band V
— — — Series B Channel 1
——— Series B Band V

The Series A results were also used in order to compare the objective noise-to-signal ratios with the subjective assessment of overall picture quality. Tables 5 and 6 show the statistical frequency distributions, mean overall subjective grading and standard deviations from the means for various noise-to-signal ratios, Table 5 showing the results for those sites having subjective noise gradings of 1, 2 or 3, and Table 6 the results for sites having subjective noise gradings of 4, 5 or 6. The reason for dividing the results in this fashion was that it was thought that if noise were sufficiently bad to be graded 4, 5 or 6, this would affect the overall assessment of picture quality and a reasonably close correlation would exist. On the other hand, if the noise were subjectively in grades 1, 2 or 3, a less close relationship between noise and overall assessment might result because other defects such as waveform distortions might predominate. The expected result did not appear, as can be seen by comparing the standard deviations in Table 5 with those in Table 6. The spread of results is scarcely greater for the low-noise sites than for the high-noise sites. The mean subjective grade for overall assessment is plotted against peak-to-peak noise/d.a.p. video signal in Fig. 2. Separate curves were derived from Table 5 and Table 6, and a third curve was obtained from all the observations. Again, it is of interest to note that the curve has an asymptote of 2 for the minimum overall subjective grading, as was the case for subjective noise gradings in Series A. From this curve it appears that if the peak-to-peak noise is less than 8% of the d.a.p. signal, measured as described in Section 2, the most probable subjective overall assessment will be grade 2 or "good". Between 8% and 20% of noise would indicate a probable assessment of grade 3, "fairly good", and a noise level between 20% and 40% should produce an assessment in grade 4, "rather poor".

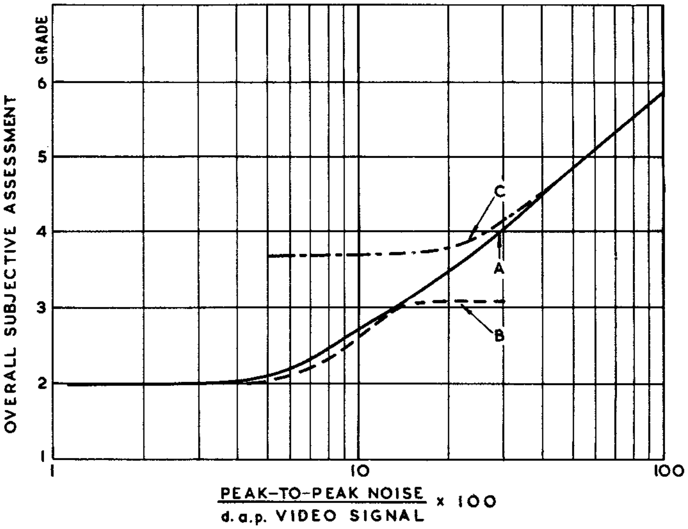

Fig. 2 - Mean overall subjective assessment plotted against noise level
(Channel I, Series A, and Band V, Series A)

A ——— All samples
B — — — Only samples with subjective noise assessment in Grades 1, 2 or 3.
C —·—·- Only samples with subjective noise assessment in Grades 4, 5 or 6.

TABLE 5

SERIES A, CHANNEL 1 AND BAND V

Distribution of noise measurements against overall assessment for samples having noise assessments 1, 2 or 3

$\frac{\text{Peak-to-peak noise}}{\text{d.a.p. video signal}}$ %	No. of samples	Per cent samples in overall subjective assessment grade heading column						Mean subjective grade	Standard deviation from mean
		1	2	3	4	5	6		
2·5	32	19	69	12				1·95	0·55
3·0	30	20	67	10	3			1·9	0·65
3·5	16	19	69	12				1·95	0·55
4·0	135	12	68	17	3			2·1	0·6
5·0	153	5	67	22	4	2		2·3	0·75
6·0	67	12	55	31	2			2·2	0·65
7·5	54	2	63	35				2·3	0·5
9·0	9		34	66				2·7	0·5
10·0	73		36	44	18	2		2·9	0·8
12·5	26		11	62	23	4		3·2	0·7
15·0	17		35	41	24			2·9	0·75
17·5	11		18	73	9			2·9	0·5
20·0	9		22	78				2·8	0·45

TABLE 6

SERIES A, CHANNEL 1 AND BAND V

Distribution of noise measurements against overall assessment for samples having noise assessments 4, 5 or 6

$\frac{\text{Peak-to-peak noise}}{\text{d.a.p. video signal}}$ %	No. of samples	Per cent samples in overall subjective assessment grade heading column						Mean subjective grade	Standard deviation from mean
		1	2	3	4	5	6		
5·0	8		12	38	25	25		3·6	0·95
7·5	10			20	80			3·8	0·45
10·0	16			44	44	6	6	3·7	0·8
15·0	25		4	16	68	12		3·7	0·7
20·0	20			40	50	10		3·7	0·65
25·0	13			23	23	54		4·2	0·85
30·0	23			22	35	43		4·2	0·8
35·0	15			20	40	40		4·2	0·75
40·0	20			10	45	20	25	4·6	1·0
50·0	9			22	22	56		4·3	0·8
60·0	15					66	34	5·3	0·6
75·0	10					34	66	5·7	0·6
100·0 +	26					19	81	5·8	0·45

4.3. Waveform Distortion

The maximum rating for waveform distortion at each site was compared with the subjective grading for overall picture quality. For this comparison it was decided to omit all sites where the presence of c.w. interference was reported by the subjective observer and all sites reported unusable because of random noise. Tables 7 and 8 show the statistical frequency distributions of sites in the various subjective grades, tabulated against the maximum rating, together with the mean subjective grades and the standard deviations from those means. Two extra columns are added at the right of the tables, which show the probable percentage of sites which would occur within ±0·5 grade and ±1·5 grade of the mean, assuming that the distribution follows the 'normal error' curve. Table 7 shows the results for Series A, Channel 1, and Table 8 shows those for Series A, Band V. The mean values from Tables 7 and 8 are plotted respectively in Figs. 3(a) and 3(b).

The results show that the waveform distortion measurement is of limited value in these conditions. Ratings better than 3% or 4% do not result in better assessments because the transmitted picture quality (including the effect of camera noise, etc.) is not sufficiently good for the mean subjective grading to improve beyond grade 2. The curves are restricted at the other end because the number of sites in which the rating exceeded 10% was statistically negligible.

The test waveform was inserted into the signal at the Switching Centre, Broadcasting House, which has a very good link to Crystal Palace. Thus, the objective measurement of waveform distortion did not include any distortion due to the programme source (at Lime Grove) or links to Broadcasting House. The maximum rating measured

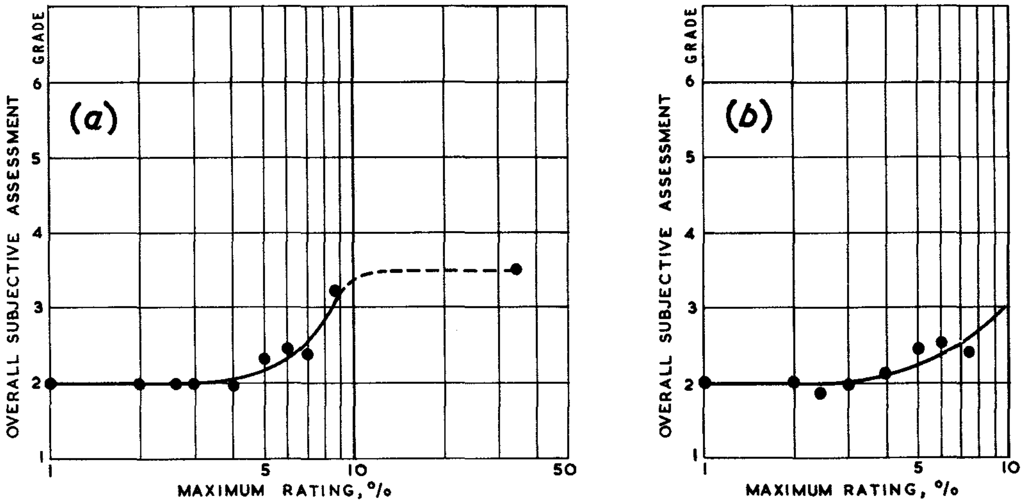

Fig. 3 - Mean subjective overall assessment plotted against maximum waveform distortion rating

(a) Channel I, Series A

(b) Band V, Series A

TABLE 7

CHANNEL 1, SERIES A

Distribution of waveform distortion measurements against overall picture quality assessments

Maximum rating %	No. of samples	Per cent samples in overall subjective assessment grade heading column						Mean assessment	Standard deviation from mean	Probable per cent within ± x of mean	
		1	2	3	4	5	6			x = 0·5	x = 1·5
1·0	4		100					2·0	0·0		
2·0	172	16	75	8	1			2·0	0·5	68	99
2·5	45	18	71	11				2·0	0·5	68	99
3·0	125	14	74	12				2·0	0·5	68	99
4·0	129	14	74	12				2·0	0·5	68	99
5·0	73	3	72	18	4	3		2·3	0·75	50	95
6·0	19	5	48	42	5			2·5	0·7	53	97
7·0	15		74	13	13			2·4	0·7	53	97
9·0	17		36	18	34	12		3·2	1·05	37	84
35·0	2			50	50			3·5	0·0		

TABLE 8

BAND V, SERIES A

Distribution of waveform distortion measurements against overall picture quality assessments

Maximum rating %	No. of samples	Per cent samples in overall subjective assessment grade heading column						Mean assessment	Standard deviation from mean	Probable per cent within ± x of mean	
		1	2	3	4	5	6			x = 0·5	x = 1·5
1·0	2		100					2·0	0·0		
2·0	74	16	68	15	1			2·0	0·6	60	99
2·5	25	20	76	4				1·9	0·45	74	99
3·0	68	18	72	9	1			1·9	0·55	64	99
4·0	103	6	75	16	3			2·2	0·55	64	99
5·0	154	6	52	34	8			2·5	0·75	50	95
6·0	60		58	34	8			2·5	0·65	56	98
7·5	36		70	22	8			2·4	0·65	56	98
10·0	42		36	31	24	9		3·1	1·0	38	87

by the mobile laboratory at a test site on Farthing Downs in Surrey was repeatedly confirmed as being between 1% and 2%. Therefore, in general, ratings greater than 2% were due to the propagation path between Crystal Palace and the site being tested. It appears that this rating can be as bad as 4% before the mean assessment of quality is appreciably deteriorated.

Fig. 4 shows a graph of the percentage of assessments which are in grades 1 and 2, "excellent" and "good", against the maximum rating factor. It will be seen that for a rating of approximately 7·5%, half the assessments will be in grades 1 and 2 and the other half in grade 3 or worse. From this it would appear that a useful quick check on the probable subjective assessment of a given site can be obtained by measuring the distortion rating as described. If the maximum figure is less than 7·5% there is a 50% probability that the assessment will be "good" or "excellent". Furthermore, if the maximum rating is less than 3% there is a 90% probability of the assessment being "good" or "excellent".

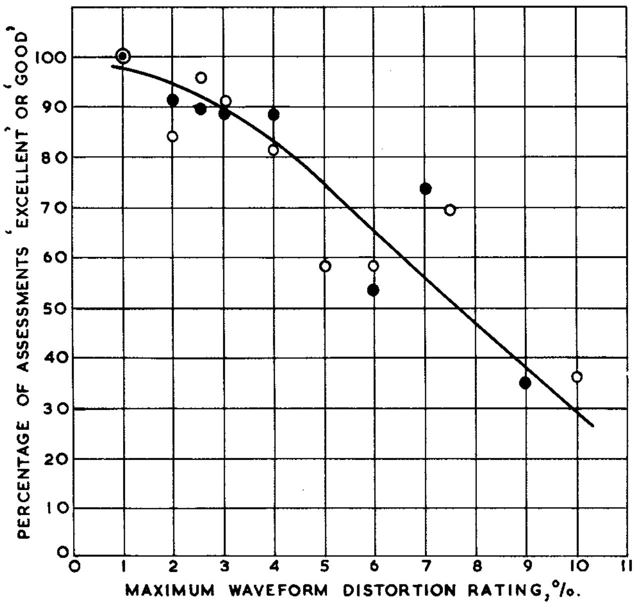

Fig 4 - Proportion of subjective assessments in Grades 1 and 2 plotted against maximum rating for waveform distortion

● Channel I

○ Band V

5. CONCLUSIONS

The semi-objective method of measuring noise-to-signal ratio agrees very closely with subjective assessments of noise level and also of overall picture quality. This merely confirms the well known fact that, statistically, the most important single parameter determining the goodness of a receiving site is the received field strength. For a level of peak-to-peak noise less than 8% of the double-amplitude-peak video signal, measured as described in Section 2, the most probable subjective overall assessment is "good"; noise levels between 8% and 20% should produce assessments of "fairly good". Noise levels in excess of 20% should result in assessments of "rather poor", "poor" or "very poor".

The waveform distortion tests can be used to predict the probable subjective assessment of picture quality as affected by waveform distortion produced by the propagation path. A maximum ratio of 3% will have a 90% probability of being assessed "good" or "excellent", and a rating of 7·5% will have a 50% chance of being so assessed.

It must be remembered, however, that c.w. and impulsive interference have not been taken into account in arriving at these conclusions.

6. REFERENCES

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